Overview of Non-Volatile Memory Packaging Needs and Approaches for Space Based Systems

1998 International Non-Volatile Memory Technology Conference

JPL

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Topics

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- Outline of NASA Unmanned Space Missions
- Non-Volatile Memory Requirements for Specific Missions
- Packaging Approaches

NASA Office of Space Science is Organized Around Four Science Themes

- **Structure and Evolution of the Universe**
  - Explain structure of the Universe and forecast our cosmic future
  - Explore cycles of matter and energy in the Universe
  - Examine ultimate limits of gravity and energy in the Universe
- **Astronomical Search for Origins**
  - How did first galaxies form?
  - How do stars and planetary systems form?
  - Are there planets outside our solar system capable of sustaining life?
  - How did life originate on Earth and is there life outside our solar system?

NASA Office of Space Science is Organized Around Four Science Themes (Cont'd)

- **Solar System Exploration**
  - Determine how solar system formed and determine if other solar systems are common in the cosmos
  - Explore history of planets
  - Understand processes that lead to life on Earth
  - Discover/investigate natural phenomena that occur in conditions not realizable in laboratories
  - Discover/inventory solar system resources that could be used by humans in the future and lay groundwork for human exploration in coming century
- **Sun-Earth Connection**
  - Observe/interpret the variable radiations in the Earth's space environment
    - Solar atmosphere and flares
    - Global magnetospheric structure and dynamics
    - Upper atmospheric structure and energetics

Selected Missions Supporting NASA Space Science Themes

Science Theme	Typical Missions
Structure and Evolution of the Universe	
	Compton Gamma Ray Observatory (CGRO)
	Extreme Ultaviolet Explorer
	Advanced X-ray Astrophysics Facility (AXAF)
	Gamma-ray Large Area Space Telescope (GLAST)
Origins	
	Hubble Space Telescope (HST)
	Space Infrared Telescope Facility (SIRTF)
	Space Interferometry Mission (SIM)
	Next Generation Space Telescope (NGST)
	Terrestrial Planet Finder (TPF)
	Planet Imager (PI)
Solar System Exploration	
	Galileo
	Cassini
	Pluto/Kuiper Express
	Europa Orbiter
	Discovery Programs (**Mars Pathfinder**, **Stardust**, Lunar Prospector, Near-earth Asteroid Rendezvous)
	New Millennium Programs (**Deep Space 1-4**, EO 1-3)
Sun Earth Connection	
	Ulysses
	Solar Probe

NVM Requirements and Packaging Approach

Cassini

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Mission Objectives
(Launch: 10/1997)

- **Science** (cloud properties/atmospheric composition, winds and temperatures, internal structure and rotation, ionosphere studies, origins and evolution)
- **Rings** (structure and composition, dynamic processes, interrelation with satellites, dust/micrometeor environment)
- **Magnetosphere** (configuration and current systems, particle composition and sources/sinks, dynamics, interaction with solar wind)
- **Titan** (atmospheric constituent abundances, distribution of trace gases and aerosols, winds and temperatures, surface state and composition, upper atmosphere)
- **Icy Satellites** (characteristics and geological histories, surface modification mechanisms, surface composition and distribution, bulk composition and internal structure, interaction with magnetosphere)

Non-Volatile Memory Requirements

2 Solid State Recorders: 250 Mbytes per recorder

Packaging Approach

NVM Requirements and Packaging Approach

Mars Pathfinder

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Mission Objectives
(Launch: 12/1996)

- Demonstrate a simple, low-cost system, at fixed price for placing a science payload on the surface of Mars at a cost < $150M
- Demonstrate mobility and usefulness of a microrover on the surface of Mars
- Science
  - Surface morphology and geology at meter scale
  - Petrology and geochemistry of surface materials
  - Magnetic properties and soil mechanics of local surface around landing site
  - Atmospheric structure and diurnal/seasonal meteorological variations

Non-Volatile Memory Requirements

Lander

- Computer: 16 Mbytes EEPROM
- Mass memory: 128 Mbytes (DRAM)

Rover

- 0.5 Mbytes EEPROM

Packaging Approach

Lander

- Conventional single chip, surface-mount packages on daughter boards

Rover

- Conventional single chip, surface-mount packages on 2 custom designed PWBs

NVM Requirements and Packaging Approach

Deep Space 1

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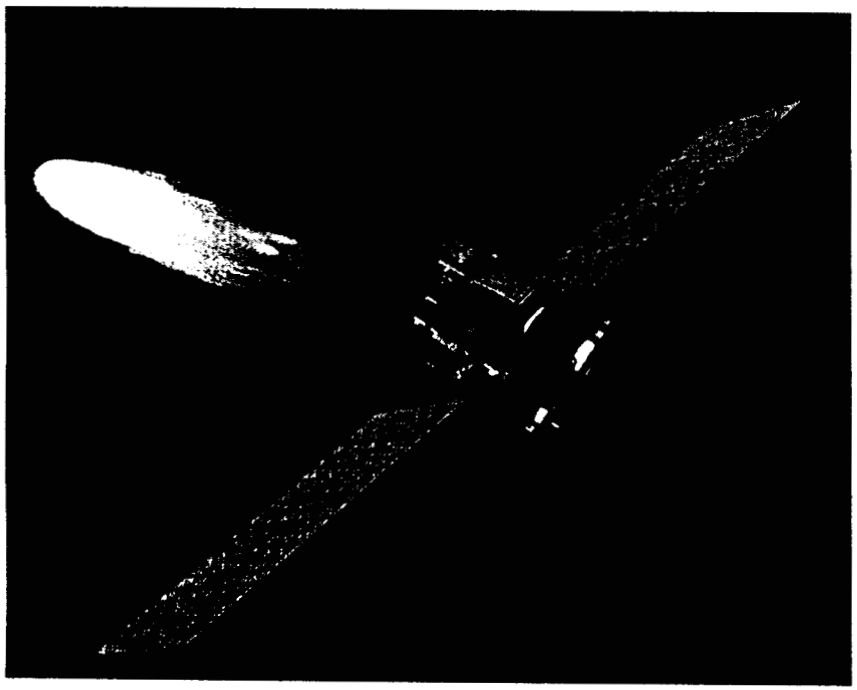

Mission Objectives
(Launch: 10/1998)

Technology Validation

- Ion engine primary propulsion system
- Autonomous optical navigation
- GaAs solar concentration array
- Integrated camera and imaging spectra
- Miniature integrated ion electron spectrometer instrument

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7 other technologies

Science Objectives

- Imaging and science flyby of asteroid 1992 KD (1999)
- Imaging and science flyby of comet Borrelly (2001)

Non-Volatile Memory Requirements

Mass Memory: 16 Mbytes

Flight Computer: None

Packaging Approach

Mass Memory

- 1 6U VME board, both sides populated
- 128K x 8 EEPROMs in MCMs

NVM Requirements and Packaging Approach

Stardust

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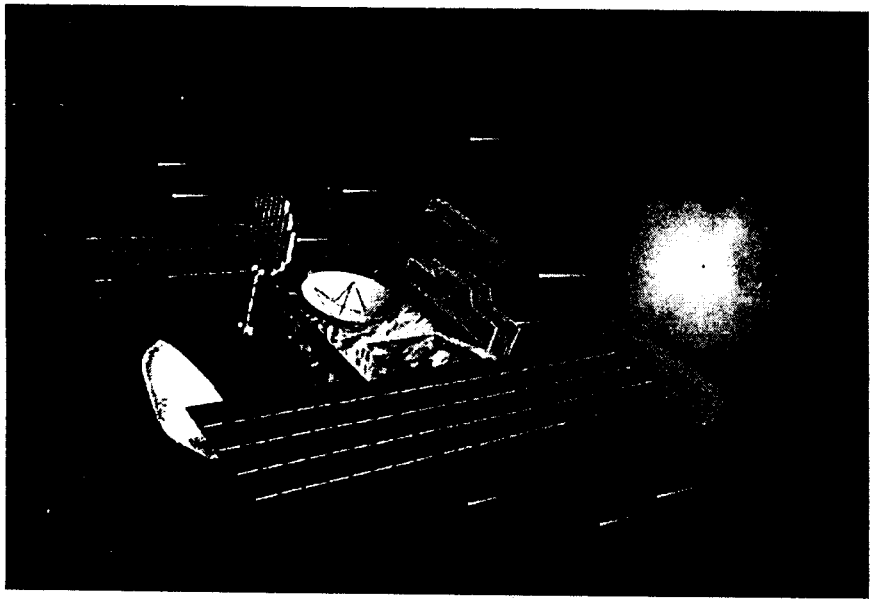


Mission Objectives
(Launch: 2/1999)

- Collect comet dust and volatile samples during close encounter with comet Wild 2
- Collect samples of interstellar dust
- Bring samples back to Earth for analysis

Non-Volatile Memory Requirements

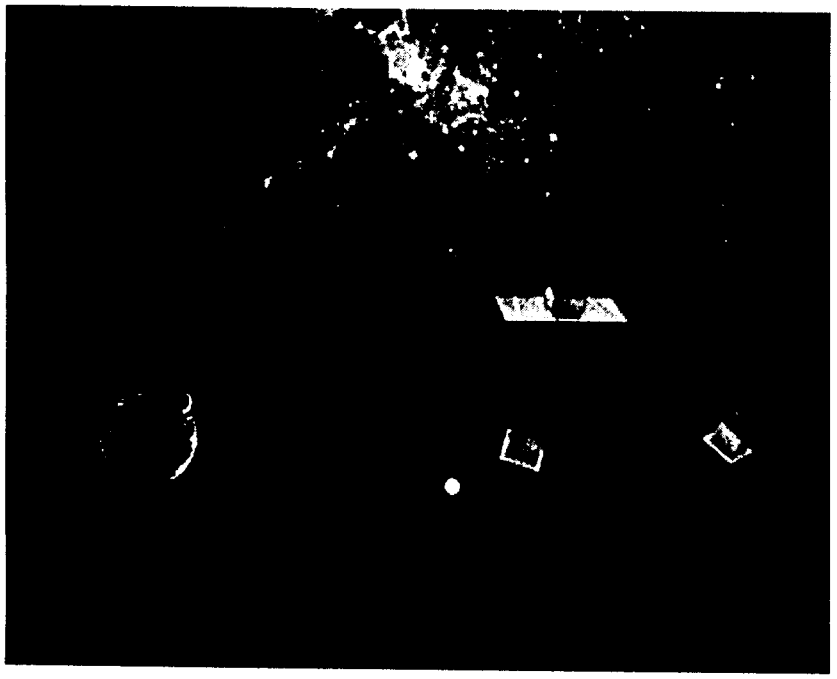
RAD 6000 flight computer with 128 Mbytes of data storage (DRAM), 3 Mbytes of non-volatile memory

Packaging Approach

- 1 6U VME board, both sides populated
- Non-volatile memory (128K x 8 EEPROMs in 3 MCMs)
- DRAM (9, 4-high DRAM stacks in 2 hermetic memory cards)

NVM Requirements and Packaging Approach

Deep Space 3



Mission Objectives
(Launch: 1/2003)

Technology Validation

- Separated spacecraft interferometer
  - Optical interferometer instruments
  - Autonomous formation flying sensor
- 15 other candidate technologies

Science Objectives

- Measure diameters of hot stars
- Directly measure the structure of several x-ray binaries
- Measure size and shape of certain "peculiar" types of stars

Non-Volatile Memory Requirements

Flight Computer: TBD

Mass Memory: 0.5 Gbytes

Packaging Approach

TBD (probably X2000 derivative)

NVM Requirements and Packaging Approach

Deep Space 4

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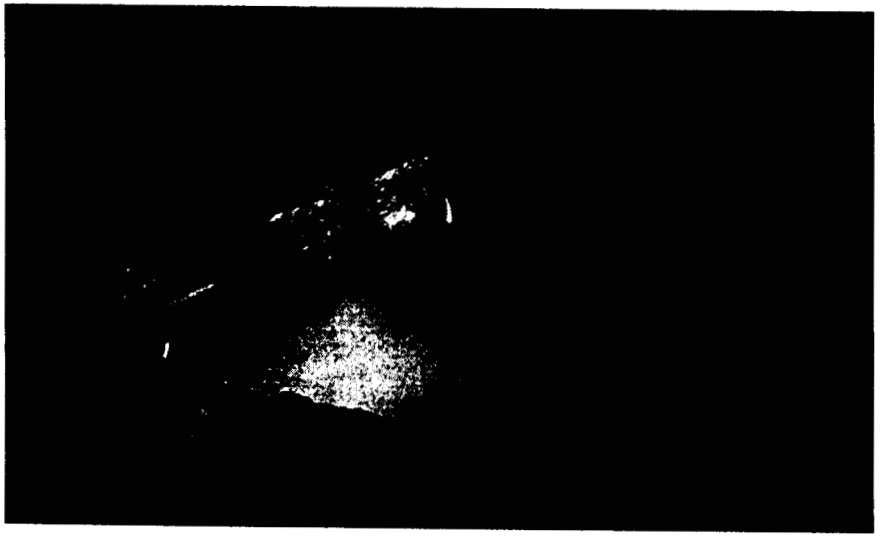

Mission Objectives
(Launch: 4/2003)

- Rendezvous with Comet Tempel 1
  - Generate maps of comet surface
  - Determine mass, shape and density of comet nucleus
- Lander
  - Analyze composition of comet surface
  - Photograph comet surface
- Return comet sample to Earth

Non-Volatile Memory Requirements

Flight Computer:

- 2 on Orbiter
  - 125 Mbytes DRAM
  - 125 Mbytes NVM
- 1 on Lander
  - 125 Mbytes DRAM

Mass Memory (Orbiter Only):

- 2 modules at 500 Mbytes per module

Packaging Approach

TBD (probably X2000 derivative)

NVM Requirements and Packaging Approach

SIM

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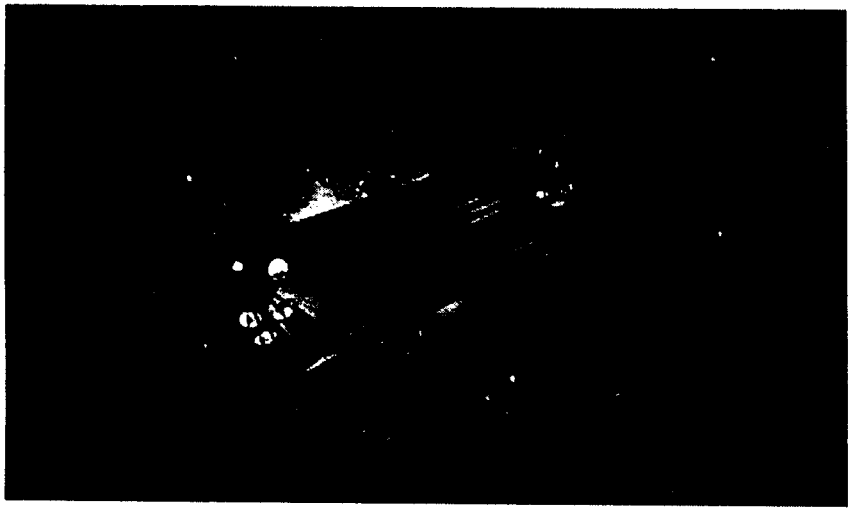

Mission Objectives
(Launch: 2004)

- Search for planets down to a few earth masses around other stars
- Calibrate stellar and "standard candle" luminousities used for cosmic distance scale
- Study dynamics of galactic disc
- Measure apparent astrometric motion in gravitational microlensing events
- Probe gravitational potential of galactic disc
- Image massive black holes in nearest active galaxies
- Direct detection of massive planets around nearby stars
- **Mass determination (or significant constraints) on black hole suspects in binary and triple systems**

Non-Volatile Memory Requirements

Flight Computer: TBD

Mass Memory: ~5 Gbyes (DRAM?)

Packaging Approach

TBD (challenging!)

NVM Requirements and Packaging Approach

Pluto/Kuiper Express

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Mission Objectives
(Launch: 11/2003)

- Characterize global geology and geomorphology of Pluto and Charon, imaging both sides of each
- Map surface composition
- Characterize Pluto's neutral atmosphere
  - Composition
  - Thermal structure
  - Aerosol particles
- Pathfinder for lower-cost exploration of the outer solar system

Non-Volatile Memory Requirements

Flight Computer:

- 3 flight computers
  - 125 Mbytes DRAM per computer
  - 125 Mbytes NVM per computer

Mass Memory:

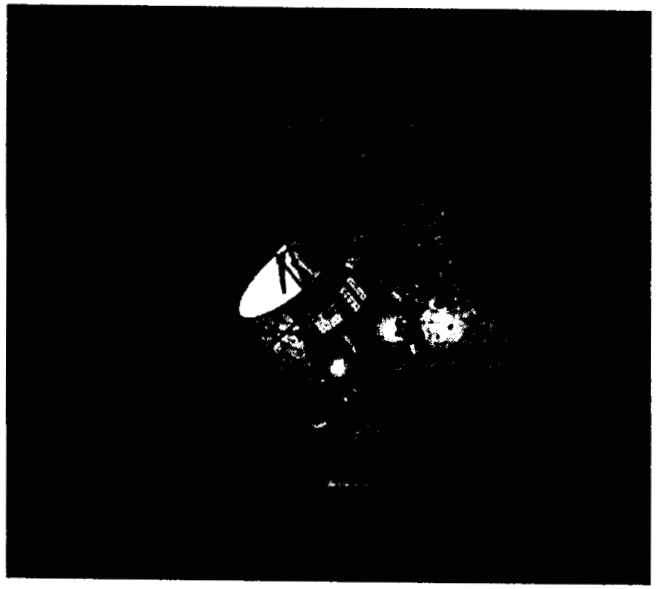
- 2 mass memory modules at 250-500 Mbytes per module

Packaging Approach

TBD (X2000 technology)

NVM Requirements and Packaging Approach

Europa Orbiter



Mission Objectives
(Launch: 11/2003)

- Determine the presence or absence of a subsurface ocean
- Characterize the three-dimensional distribution of subsurface liquid water and its overlying ice layers
- Characterize the morphology of the surface and identify sites of recent or current activity

Non-Volatile Memory Requirements

Flight Computer:

- 3 flight computers
  - 125 Mbytes DRAM per computer
  - 1 Gbyte NVM per computer
- 1 on Lander
  - 125 Mbytes DRAM

Mass Memory:

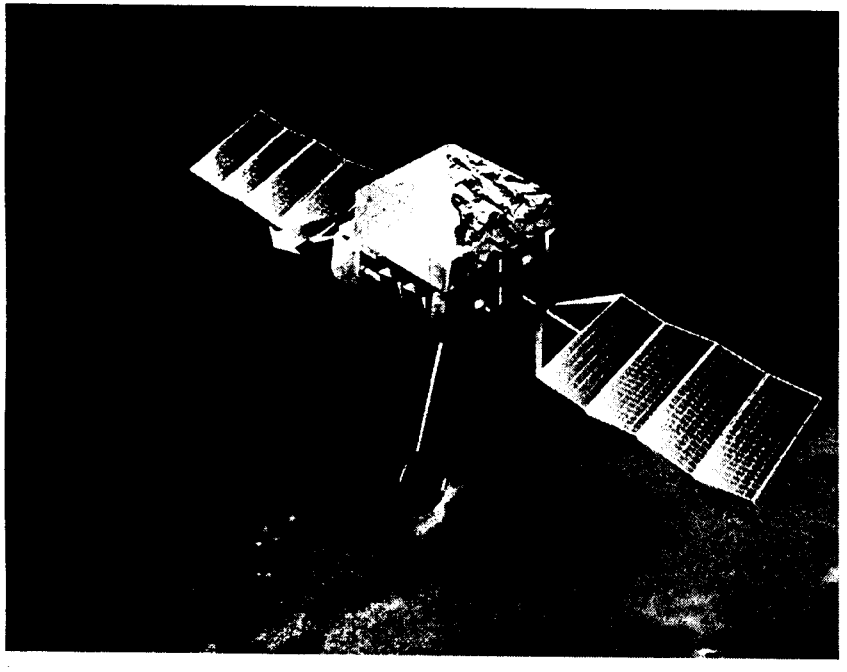
- 2 mass memory modules at 250-500 Mbytes per module

Packaging Approach

TBD (X2000 technology)

NVM Requirements and Packaging Approach

GLAST



Mission Objectives
(Launch: TBD)

- Determine mechanisms of active galactic nuclei formation
- Determine type of objects and mechanisms for gamma ray emission from unidentified sources observed by Compton Gamma Ray Observatory
- Determine if high energy background is resolvable into point sources or if it is a diffuse component
- Provide constraints on physical mechanisms for gamma ray burst
- Provide direct evidence of proton cosmic-ray acceleration in supernova remnants by gamma-ray mapping and energy spectral measurements
- Probe cosmic-ray distribution in dense molecular cloud and in nearby galaxies

Non-Volatile Memory Requirements

TBD

Packaging Approach

TBD

NVM Requirements and Packaging Approach

NGST

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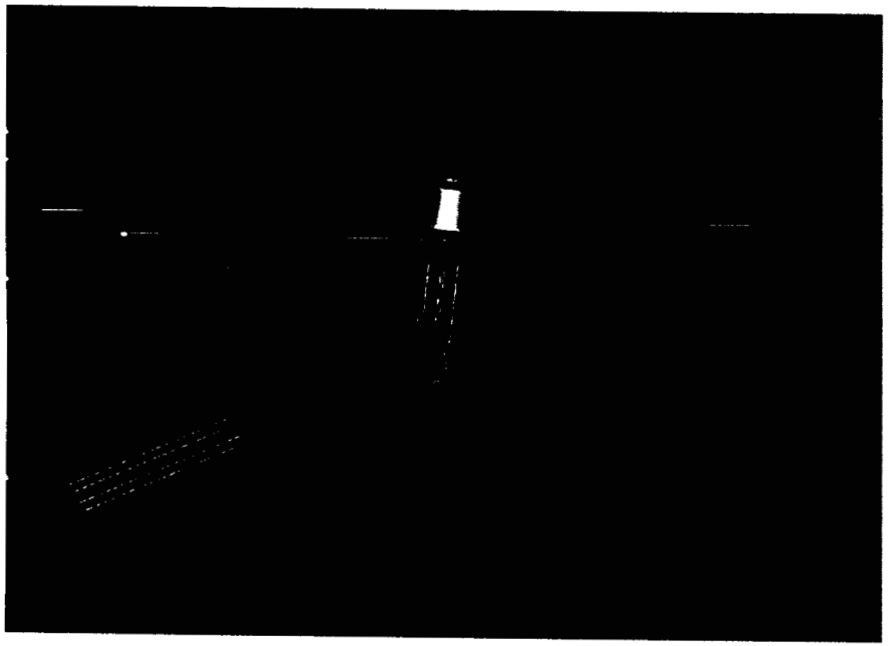


Mission Objectives
(Launch: Q1/2008)

- Study birth of first galaxies
- Determine shape and fate of the Universe
- Study formation of stars and planets
- Observe the chemical evolution of the Universe
- Probe the nature of dark matter

Non-Volatile Memory Requirements

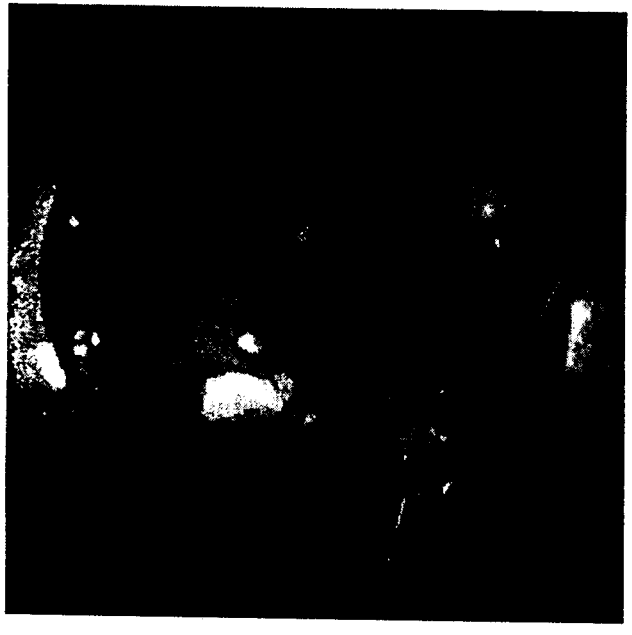
Solid State Recorder: 10 Gbytes

Packaging Approach

TBD (challenging!)

NVM Requirements and Packaging Approach

Solar Probe



Mission Objectives
(Launch: 2/2007)

- Fly through the solar corona to investigate:
  - What heats the corona and accelerates the solar wind
  - Where sources of solar wind originate
  - The roles of waves and turbulence in coronal heating
  - Processes that accelerate, store and transport energetic particles in the corona

Non-Volatile Memory Requirements

Flight Computer:

- 3 flight computers
  - 125 Mbytes DRAM per computer
  - 125 Mbytes NVM per computer

Mass Memory:

- 2 mass memory modules at 250-500 Mbytes per module

Packaging Approach

TBD (X2000 technology)

Typical Packaging Approaches: Current and Future Missions

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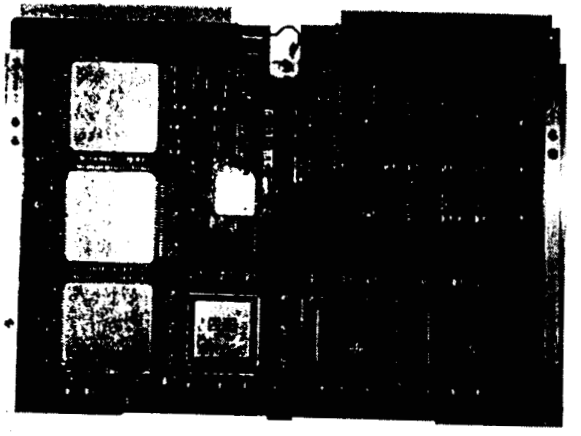
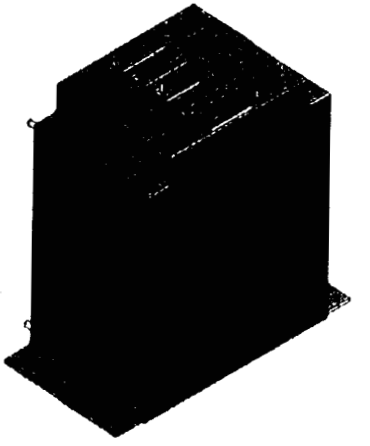
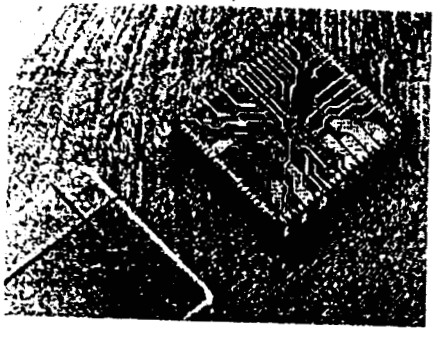
Standard Surface Mount Assembly with MCMs

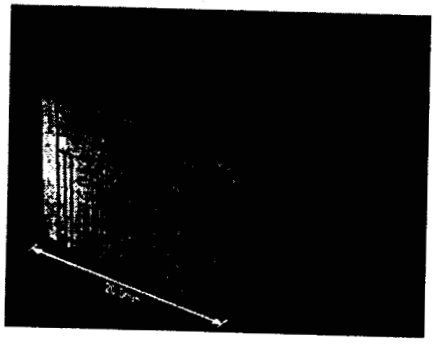


X2000 Technology

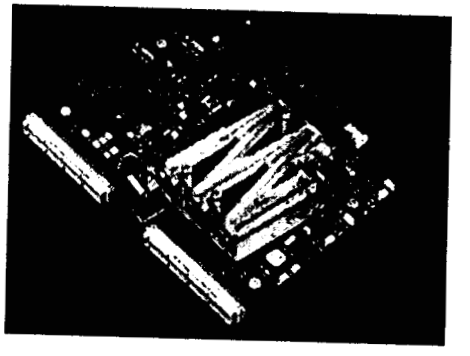


Standard Die





Optical Memory



Summary

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- **Missions Drive Non-Volatile Memory Requirements**
  - Memory Space
  - Volume
  - Weight
  - Cost
  - Availability
  - Radiation, other environmental issues
- **Origins Missions will be most demanding in terms of memory size**